EFFECTS OF VARYING FIRE REGIMES ON ANNUAL GRASSLANDS IN THE SOUTHERN SIERRA NEVADA OF CALIFORNIA

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ABSTRACT

Effects of up to three successive spring and fall burns on composition and biomass of the predominantly non-native grasslands of the southern Sierra Nevada foothills were evaluated. Fall and spring burning regimes increased the number and biomass of both alien and native forb species. No native grass species became established following the treatments. Thus, whereas the biomass of alien grass species can be reduced by repeated burning, they will be replaced by increases in both alien and native forbs. Changes seen following one or two burns (spring or fall) were not sustained following cessation of burning treatment.

The annual grasslands that characterize much of California, including the low elevation foothills of the southern Sierra Nevada, are dominated by species native to the Mediterranean Basin (Wester 1981). Prior adaptation to grazing by livestock has favored alien species in the replacement of native grasses and forbs (Barry 1972; Jackson 1985; Macdonald et al. 1988). Analysis of both historical accounts and microfossil remains indicate that areas that once supported either extensive native annual grasslands or *Stipa* bunchgrass prairie are now dominated by alien annual grasses (Barry 1972; Heady 1977; Bartolome et al. 1986). The abilities to withstand drought and grazing have combined to assure the continued dominance of annual Mediterranean grasses. The timing and intensity of precipitation and grazing pressure, including the amount of natural mulch retention, have been shown to significantly influence vegetative production and species composition on annual grassland sites in central California (Talbot et al. 1939; Duncan and Woodmansee 1975; Bartolome et al. 1980). Hervey (1949) quantified the effects of an early summer burn in temporarily favoring broadleaved forbs over grasses on a coastal foothill range and Larson and Duncan (1982) have documented a near doubling of production two years following a fall burn on the San Joaquin Experimental Range near Fresno. Yet, although variable patterns of climate, fire and grazing

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result in considerable year to year fluctuation in nonnative annual species composition and biomass (Bentley and Talbot 1958; Heady 1958; Pitt and Heady 1978), those studies showed no indication of successful reestablishment of the native flora.

Land management agencies charged with the preservation of natural ecosystems face the dilemma of either accepting the loss of a significant component of the native flora or attempting to restore a more native species composition. The former, as has been suggested by Heady (1977), requires a compromise in management objectives, essentially declaring alien species as naturalized. The latter requires both a sophisticated knowledge of grassland ecology and a potentially intensive restoration program, if such is even possible. In Sequoia National Park, several thousand hectare of annual grassland are protected as both part of the Park and the Sequoia and Kings Canyon International Biosphere Reserve. National Park Service management policy calls for protection and restoration of this ecosystem. Although effective protection from livestock grazing is provided, the question remains as to whether native species can ever successfully be restored to the area.

An active program of restoring periodic fire to an area where fires have been effectively suppressed for most of a century (Parsons 1981; Bancroft et al. 1985), together with evidence that the frequency and season of fire can influence species composition and production in other grassland communities (Hover and Bragg 1981; Towne and Owensby 1984), led us to test the effects of varying fire regimes on species composition and biomass. Similar experiments, using a combination of seeding, fertilization, and burning, provided mixed results in restoring degraded grasslands in San Diego County (Garcia and Lathrop 1984).

The objectives of this study were to investigate the effects of frequency and season of burning on the relative composition and dominance of native and alien species in the annual grassland communities of the southern Sierra Nevada. Such data are essential to understanding the effects of past and present management practices as well as in evaluating the possibility of using fire as a tool to reestablish native species. This is critical to understanding the short- and long-term impacts of reestablishing natural fire regimes (Parsons et al. 1986).

Study Area

The study area is located on a gentle eastern exposure at an elevation of 700 m in the rolling foothills of the drainage of the Middle Fork of the Kaweah River, Sequoia National Park, Tulare County, California. The region is characterized by the hot, dry summers typical of Mediterranean climates (Aschmann 1973). Annual precipitation, which is concentrated in January, February, and March, averaged 139, 73, 133, and 202 percent, respectively, of the long-term annual average of 68.1 cm during the four study years. Vegetation in the area consists of annual grasslands beneath scattered blue oak (*Quercus douglasii* Hook. & Arn.). Grazing by domestic cattle and horses occurred on the site during the late 1800's and early 1900's but has now been absent for at least 60 years.

The area has no record of burning after a 1960 wildfire burned much of the vicinity (Stocking 1966). Park fire maps record no fires in the area between 1925 and 1960. Prior to the fire protection provided by the creation of Sequoia National Park in 1890, lightning fires, together with intentional ignitions by aboriginals and sheepherders (for a brief period between about 1860 and 1890), are thought to have regularly burned the Sequoia foothills (Vankat and Major 1978; Parsons 1981). Previous studies of vegetation in the area have focused primarily on the overstory oak woodland (Baker et al. 1981; McClaran 1986), and nearby chaparral communities (Stohlgren et al. 1984; Rundel et al. 1987). Soils in the area are characterized by fine to coarse textured sandy loam Ultic Haploxeralfs (Huntington and Akeson 1988). They are derived from granitic bedrock and are moderately deep and moderately well drained.

Methods

An area approximately 2.0 ha was selected as representative of the foothill annual grasslands of Sequoia National Park. Seven 10-m by 10-m study sites were identified within this area in positions that maximized chances of successful fire control. The sites were each assigned one of seven fire treatments based on fire logistical concerns. Treatments included a single fall burn (1980; F1), two successive fall burns (1980 and 1981; F2), three successive fall burns (1980, 1981, and 1982; F3), a single spring burn (1980; S1), two successive spring burns (1980 and 1981; S2), three successive spring burns (1980, 1981, and 1982; S3), and an unburned control (C). All fires were carried out as prescribed burns under pre-established prescriptions previously tested to assure both containment and high fuel consumption.

Fall burns were conducted in late October or early November, near the end of the natural fire season (Parsons 1981). During the fall burns fine fuel (cured grass) moisture contents ranged from 10 to 15%, air temperatures from 18 to 21°C, and relative humidities from 40 to 65%. Flame lengths averaged 0.6 to 1.0 m and rate of spread 2.5 to 5.0 m/min. The spring burns were carried out in early to mid-June, after the annual vegetation had dried but before most natural ignitions would normally have occurred (Parsons 1981). Fine fuel moistures ranged from 7 to 9%, air temperatures from 22 to 27°C and relative humidities from 41 to 46%. Flame lengths ranged from 0.6 to 1.5 m and rate of spread from 4.0 to 20 m/min. All burns resulted in essentially total consumption of vegetative biomass. Burning during the hot dry summer was avoided due to the threat of the fire escaping the area.

Vegetation sampling was carried out annually within five randomly distributed 0.05-m^2 circular plots within each burn treatment (new plots were selected each year). Beginning in the spring of 1980, before the first burn, and continuing through 1983, one growing season following the final burn, all of the current year's vegetative growth was clipped at a height of 1.0 cm above ground level in each plot. Clipped samples were separated by species and oven dried for 24 hours at 94°C to determine dry weight. Sampling was carried out in the spring at peak biomass, before significant seed loss or senescence had occurred. The sampling schedule varied as a function of that year's phenology, falling between 4 May and 24 May. Data collected from the 35 randomly placed 0.05-m^2 plots sampled during the spring of 1980 were used to characterize the pre-study species composition and biomass of the area.

It is recognized that the lack of true replicate treatments may limit interpretation of the data. Due to logistic constraints related to the burn operation the decision was made to focus on multiple treatments at the expense of replication. Possible block effects are minimized by also considering the results as a percent of the 1980 preburn condition of the same plots. Statistical analysis of the vegetation data included two-way analysis of variance (ANOVA) to compare the effects of treatment, or burning regime, by year for each of three vegetative groups (alien grasses, alien forbs, and native forbs; no native grasses were encountered) for biomass and species richness. If the F-test ratios were significant ($p < 0.05$) for either factor, Tukey's multiple range test (SAS Institute Inc. 1985) was used to detect significant differences ($p < 0.05$) within the vegetative groups for that factor. We recognize the study design does not fully meet the underlying assumption of an analysis of variance since plots were not randomly assigned treatments (due to fire control logistics constraints). But because of the homogeneity of the pre-burn condition and the severity of the treatments applied, we present the results of the ANOVA as supportive information.

To assess species-specific responses to different burning regimes, percent of total biomass for each major species was calculated following the three successive fall or spring burns and compared to that both preceding treatment (1980) and for the 1983 control.

Results and Discussion

The pre-burn 1980 vegetation of the study sites consisted of eighteen species of grasses and forbs with a mean total biomass of 334.5 g/m^2 (Table 1). The 35 sample plots averaged 5.6 species per plot.

TABLE 1. COMPOSITION OF FOOTHILL GRASSLANDS, SEQUOIA NATIONAL PARK. Data based on spring 1980 sampling of 35 randomly placed 0.05-m^2 plots in the seven 100-m^2 study sites. Frequency refers to percentage of the 35 plots in which species occurs.

Species	Growth form	Alien/native	Frequency	Biomass $g/m^2 \pm SE$
Avena fatua L.	grass	A	100	254.1 ± 18.57
Bromus mollis L.	grass	A	97	33.7 ± 5.86
Bromus diandrus Roth	grass	A	83	36.3 ± 5.52
Galium parisiense L.	forb	A	46	1.0 ± 0.42
Brodiaea elegans Hoover	forb	N	37	0.8 ± 0.26
Bromus sterilis L.	grass	A	29	1.8 ± 0.71
Torilis nodosa (L.) Gaertner	forb	A	26	1.6 ± 0.66
Festuca dertonensis Asch. & Graebner	grass	A	23	2.6 ± 1.33
Cerastium glomeratum Thuill.	forb	A	23	0.2 ± 0.09
Madia elegans D. Don	forb	N	20	0.2 ± 0.14
Trifolium microcephalum Pursh	forb	N	20	0.8 ± 0.32
Amsinckia intermedia Fischer & C. Meyer	forb	N	17	0.7 ± 0.35
Lotus subpinnatus Lagasca	forb	N	9	0.1 ± 0.08
Geranium carolinianum L.	forb	N	6	0.2 ± 0.12
Festuca megalura Nutt.	grass	A	6	0.1 ± 0.07
Plagiobothrys nothofulvus (A. Gray) A. Gray	forb	N	6	0.1 ± 0.02
Euphorbia crenulata Engelm.	forb	N	6	0.1 ± 0.02
Lupinus benthamii A. A. Heller	forb	N	3	0.1 ± 0.11

TABLE 2. EFFECT OF TREATMENT BY YEAR ON NUMBER OF SPECIES AND BIOMASS (g/ 0.05 m^2) OF ALIEN GRASSES. Only means with different letters within columns (a, b, c) or within rows (i, j, k) are significantly different at $p < 0.05$. Treatment codes are C = control, F1 = one fall burn, F2 = two fall burns, F3 = three fall burns, S1 = one spring burn, S2 = two spring burns, S3 = three spring burns.

	Year			
Treatment	1980	1981	1982	1983
		No. species		
C	3.0	3.8	3.0	3.0 a
F1	3.0	2.4	3.6	3.0 a
F2	3.8	3.2	3.2	3.6 a
F3	3.4	3.6	3.4	2.6 b
S1	4.4	3.4	3.4	3.4 a
S2	3.8	4.4	4.4	3.8 a
S3	3.0	3.2	3.8	4.0 a
		Biomass		
C	14.4	13.3	17.8 i	10.4 c/j
F1	15.0	17.0	11.2	9.1
F2	20.0 i	14.1	6.7 j	12.3 c/j
F3	19.2 i	17.3 i	9.4	2.3 a/j
S1	13.2	14.4	18.1	17.3 b
S2	18.3 i	11.3	8.6 j	8.6 j
S3	15.0	11.9	8.6	8.1 c

Avena fatua, a grass introduced from Europe, dominated all plots, constituting 75.0% of the total biomass (range = 63.2 to 89.7%). Three alien grass species, *A. fatua, Bromus mollis*, and *B. diandrus,* occurred in nearly every plot and together accounted for 95.5% (range = 90.3 to 99.6) of the total biomass. Broadleaved forbs occurred only sporadically, constituting 5.9 g/m^2 or 1.8% (range = 0 to 10.1%) of the total mean biomass. Alien forbs averaged less than one species and 2.8 g/m^2 whereas native forbs averaged 1.3 species and 3.1 g/m^2. Non-native species dominated all plots in both frequency and biomass. Although a total of nine native species were encountered, only *Brodiaea elegans* was found in more than 20% of the plots, and all nine together accounted for less than one percent of the total biomass (Table 1). This pre-treatment composition is similar to that found in other ungrazed or lightly grazed California annual grassland sites (Heady 1977).

The only detected pre-burn significant differences between plots located in the different treatment areas were for number of species and biomass of alien forbs in the site to receive a single spring burn (S1) and biomass of native forbs in the site to receive two successive spring burns (S2). The only significant differences found between years for the control plot were for biomass of alien grasses (1982–1983), and number of species of alien forbs (1980–1981) (see Tables

TABLE 3. EFFECT OF TREATMENT BY YEAR ON NUMBER OF SPECIES AND BIOMASS (g/ 0.05 m^2) OF ALIEN FORBS. Only means with different letters within columns (a, b, c) or within rows (i, j, k) are significantly different at $p < 0.05$. Treatment codes are C = control, F1 = one fall burn, F2 = two fall burns, F3 = three fall burns, S1 = one spring burn, S2 = two spring burns, S3 = three spring burns.

	Year			
Treatment	1980	1981	1982	1983
		No. species		
C	0.4 a/i	2.4 a/j	1.2 a	1.2 a
F1	0.6 a/i	2.4 a/j	3.6 b/j	2.4 j
F2	1.0 i	5.4 b/j	4.2 b/j	3.6 b/k
F3	0.8 a/i	3.2 j	3.8 b/j	4.0 b/j
S1	2.6 b	3.6	3.8 b	2.8
S2	0.6 a/i	2.6 a/j	3.4 b/j	3.2 j
S3	0.8 a/i	3.6 j	4.0 b/j	4.0 b/j
		Biomass		
C	0.1 a	0.3 a	0.8 a	0.8 a
F1	0.01 a/j	1.9 j	7.6 b/i	1.9 j
F2	0.1 a/j	2.9 j	7.3 b/i	2.7 b/j
F3	0.03 a/i	4.2 b/j	3.6 j	5.4 b/j
S1	0.7 b	1.5	2.8	1.2
S2	0.03 a/i	0.7 i	1.7 a/j	3.2 b/k
S3	0.1 a/i	2.1 i	8.1 b/j	4.3 b/j

2–4). This shows strong similarity between the pre-burn character of the seven treatment areas as well as a consistent year to year character for the unburned control.

Two-way ANOVA of treatment and year for each vegetation group detected significant effects ($p < 0.05$) of both treatment and year on all but the number of alien grass species. Treatment effects influenced the biomass of the different vegetation groups as well as the number of native and alien forb species.

Together, the burn treatments resulted in the appearance of 18 additional native forb species, five additional alien forb species, and no new grass species. The most important of these species are discussed in the text.

Figures 1 and 2 summarize the effects of one, two, and three successive fall and spring burns on the relative biomass of alien grasses, alien forbs and native forbs. Under both burning regimes the biomass of alien grasses is decreased relative to that of both alien and native forbs. Tables 2–4 detail the effects of the six experimental burning regimes on number of species and biomass of these three vegetative groups.

Alien grasses appear to be minimally affected by the fall burning regimes. Species richness (and composition) is not influenced by successive fall burns (Table 2). Whereas biomass of alien grasses is

TABLE 4. EFFECT OF TREATMENT BY YEAR ON NUMBER OF SPECIES AND BIOMASS (g/ 0.05 m^2) OF NATIVE FORBS. Only means with different letters within columns (a, b, c) or within rows (i, j, k) are significantly different at $p < 0.05$. Treatment codes are C = control, F1 = one fall burn, F2 = two fall burns, F3 = three fall burns, S1 = one spring burn, S2 = two spring burns, S3 = three spring burns.

Treatment	Year			
	1980	1981	1982	1983
		No. species		
C	0.6	1.2 a	0.8 a	1.6 a
F1	1.0	3.0	2.2	1.0 a
F2	2.0	3.0	3.4	3.6 b
F3	0.4 i	3.0 j	1.8	4.2 b/j
S1	1.4	3.6 b	3.2	1.6 a
S2	2.6 i	5.8 b/j	4.4 b/j	2.2 i
S3	1.0 i	4.4 b/j	3.2 j	3.2 j
		Biomass		
C	0.1 a	0.7 a	0.37	0.5 a
F1	0.01 a/i	6.4 j	0.8 i	0.4 a/i
F2	0.2 a	3.1	6.2	2.5
F3	0.02 a/i	6.2 j	1.5	2.1
S1	0.6 a/i	12.4 b/j	2.1 i	0.9 i
S2	0.6 b/i	5.9 j	3.3	0.8 i
S3	0.1 a/i	5.3 j	2.9	3.5 b

decreased over pre-treatment levels by two fall burns, it is only after three such burns that biomass (11% of pre-burn) also differs from numbers found in the control plots. Decreases in abundance of *Avena fatua* and *Bromus diandrus* account for most of the biomass change.

Both the number of species and biomass of alien forbs increased over pre-burn and control levels following two or more fall burns (Table 3). Alien forb biomass increased as much as 12,000% following two fall burns (F2; 1982) and 18,000% following three fall burns (F3; 1983) over pre-burn levels in the same plots. Although an increased number of species is still evident following a year of recovery in the F2 plot, biomass has dropped markedly (Table 3). A single species, *Centaurea melitensis* L., which was not encountered in any plots during pre-burn sampling and only rarely found in the control plots in succeeding years, accounts for the majority of the alien forb response. Other alien forb species that increased with fall burning include *Silene gallica* L., *Galium parisiense*, and *Hypochoeris glabra* L.

Whereas native forbs increased in both species richness and biomass following fall burning, only the number of species following three successive fall burns (F3) differed from both pre-burn and control levels (Table 4). Native forb biomass increased sharply following an initial burn and maintained moderately high levels in the following years. *Lotus subpinnatus* and *Orthocarpus attenuatus* A. Gray were the native forb species exhibiting the largest and most consistent increases following fall burning. Although up to three successive fall burns clearly influenced relative species composition and dominance, including increasing the relative importance of both native and alien forbs at the expense of alien grasses (Fig. 1) it is uncertain what fire return interval would be required to maintain such changes or whether they would revert to pre-burn levels following a short time without fire. By the end of the study in 1983, it is only in the plot burned for three successive years (F3) that alien grasses do not dominate total biomass. Increases in the forb groups following one or two burns in the other fall treatments either have returned or have begun to approach pre-burn levels. Additional time would be required to determine if the relative suppression of alien grasses achieved with three fall burns could be maintained.

Whereas total biomass tended to increase following an initial fall burn, it returned to near control levels in succeeding years. The minimal influence of repeated fall burning on total productivity counters other findings that the amount of mulch residue strongly influences productivity in California's annual grasslands (Bartolome et al. 1980).

Spring burning, although probably not as important a part of historical southern Sierra Nevada foothill fire regimes as summer and fall burns, does show some potential for altering composition of annual grasslands. Total species richness was increased by successive spring burns, a difference due entirely to increased numbers of forbs. Total biomass was not influenced by spring burning (Tables 2–4). Spring burning showed little effect on alien grasses, other than a substantial but not statistically significant decrease in biomass (Table 2, Fig. 2).

Species richness and biomass of alien forbs increased following two or three spring burns. Biomass (Fig. 2) increased by as much as 135-fold (from 0.1 to 8.1 g/0.05 m^2) in the 1982 F3 plot (Table 3). Alien forb species, including *Silene gallica* L., *Erodium botrys* (Cav.) Bertol., and *Hypochoeris glabra* L., increased significantly following spring burns.

An initial spring burn dramatically increased both the number of species and biomass of native forbs. However, these increases either returned to near pre-burn levels with the cessation of fire (S1 and S2) or stabilized at slightly lower levels even with repeated annual burning (F3; Table 4). *Trifolium microcephalum, Lupinus benthamii,* and *Lotus subpinnatus* are the major native forbs that increased following spring burning. Increases in *L. benthamii* were not sustained following the initial burn.

Table 5 lists those species that were influenced most by three

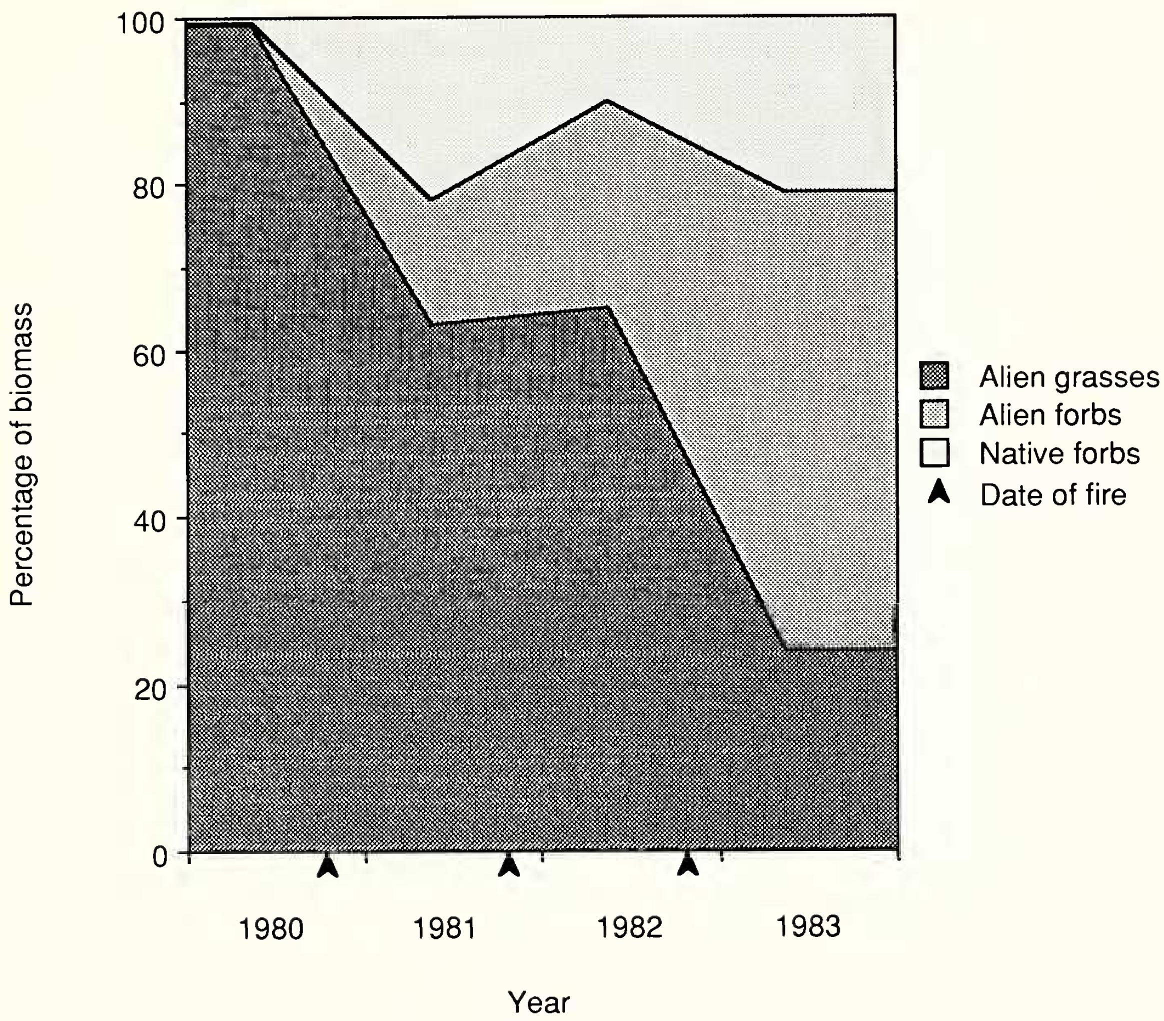

FIG. 1. Percentage of total plot biomass for alien grasses, alien forbs, and native forbs following 1, 2, and 3 successive fall burns. Data from 5 0.05-m² plots located in F3 (three fall burns) treatment.

successive fall or spring burns. Burning in either season resulted in dramatic reductions in dominance of the omnipresent *Avena fatua.* This invasive European grass dominates much of the annual grasslands throughout California. Three successive fall burns reduced *A. fatua* to 5.3% of the total biomass whereas three successive spring burns reduced it to 12.4% (Table 5). A second common introduced grass, *Bromus diandrus,* was also reduced to minimal presence (0.2 and 1.3%, respectively) by successive fall or spring burns. The third dominant grass of the unburned grassland, *Bromus mollis,* was not significantly affected by burning in either season, contributing between 10 and 27% of the total biomass of both pre- and post-burn plots.

Both the F3 and S3 treatments shifted the relative dominance of both species number and biomass from grasses to forbs. Successive fall burns resulted in a dramatic increase of the alien forb *Centaurea melitensis* from non-existent in 1980 to 46.3% of the total biomass in 1983. Alien and native forbs together accounted for 8.2 of the

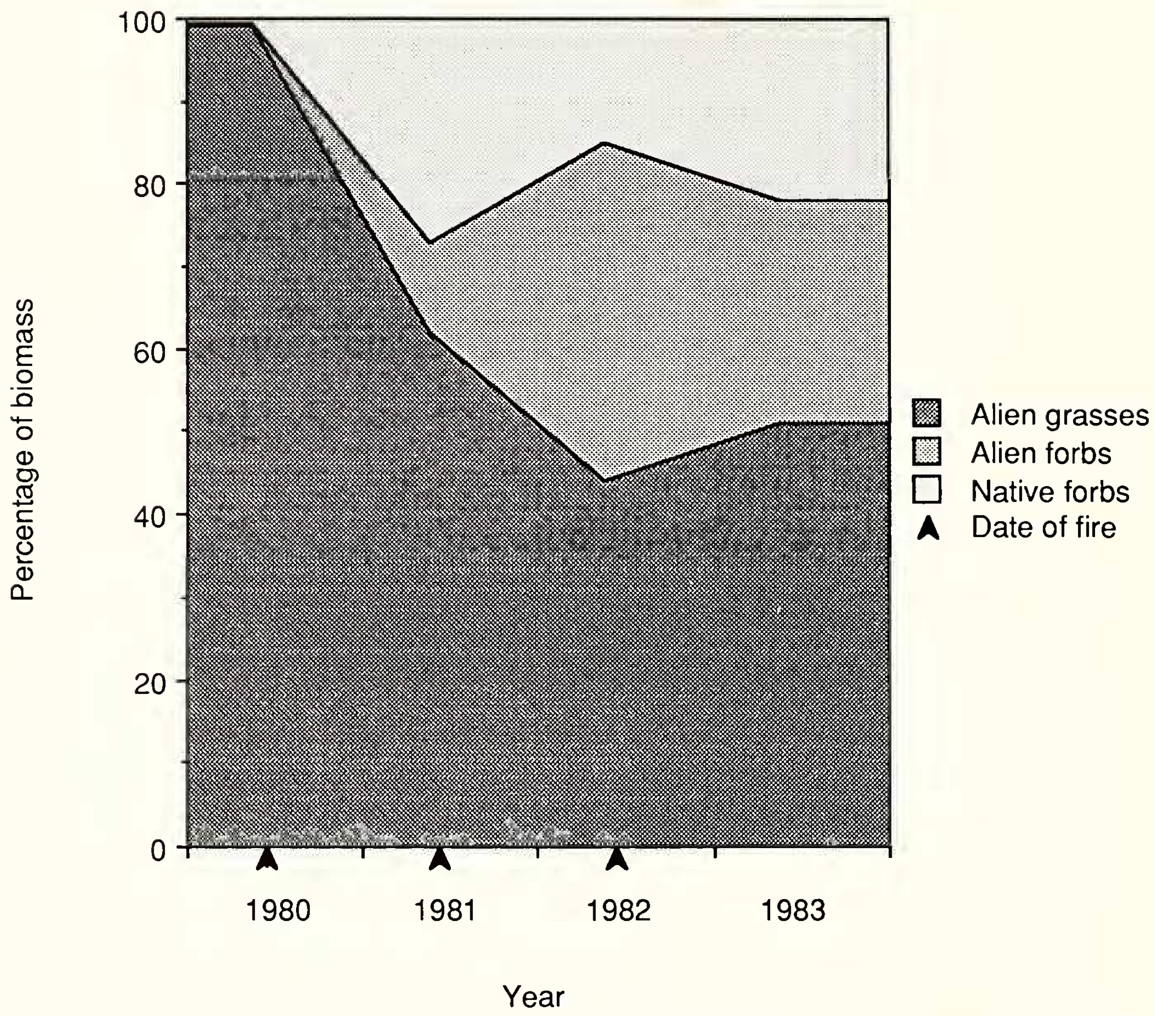

FIG. 2. Percentage of total plot biomass for alien grasses, alien forbs, and native forbs following 1, 2, and 3 successive spring burns. Data from 5 0.05-m^2 plots located in S3 (three spring burns) treatment.

average 10.8 (76%) species per plot (as compared to 1.2 of the 4.6 or 26% in the same plots before burning and 2.8 of 5.8 or 48% of the 1983 control plots) and 7.5 of the average 9.8 g/0.05 m^2 (76%) (as compared to 0.05 of 19.2 g/0.05 m^2 or 0.2% before burning and 1.3 of 11.7 or 11% of the control plots). Five species of forbs (3 alien and 2 native) accounted for 71.6% of the total post-treatment biomass. The same five species were completely absent from these plots in 1980 and together accounted for only 0.3% of the total biomass in the 1983 control plots (Table 5). A total of six native and six alien forb species were encountered following the three fall burns.

While three successive spring burns also increased the relative importance of forbs over grasses, the magnitude of the shift was less and the species composition different from that observed following fall burning. The five most common forbs following three successive spring burns included two native and three alien species. Together these contributed 43.6% of the total biomass (Table 5). A total of

TABLE 5. SPECIES SHOWING MAJOR CHANGE IN RELATIVE BIOMASS FOLLOWING THREE SUCCESSIVE FALL (F3; 1983) AND/OR THREE SUCCESSIVE SPRING (S3; 1983) BURNS AS COMPARED WITH PREBURN (1980) AND CONTROL (C; 1983) PLOTS. Data presented as percentage of total plot biomass. Growth form codes are A = alien, N = native, F = forb, G = grass.

Species	Growth form	Control (1983)	Preburn (1980)	Postburn (1983)
Fall burn increasers				
Centauria melitensis	AF	0.1	0.0	46.3
Lotus subpinnatus	NF	0.0	0.0	10.8
Silene gallica	AF	0.1	0.0	5.3
Hypochoeris glabra	AF	0.1	0.0	4.8
Orthocarpus attenuatus	NF	0.0	0.0	4.4
Fall burn decreasers				
Avena fatua	AG	39.0	89.7	5.3
Bromus diandrus	AG	12.0	10.8	0.2
Spring burn increasers				
Erodium botrys	AF	0.0	0.0	15.8
Trifolium microcephalum	NF	0.1	0.5	11.0
Silene gallica	AF	0.1	0.0	7.5
Lotus subpinnatus	NF	0.0	0.0	6.9
Festuca megalura	AG	0.0	0.1	6.2
Centauria melitensis	AF	0.1	0.0	2.4
Spring burn decreasers				
Avena fatua	AG	39.0	76.5	12.4
Bromus diandrus	AG	12.0	12.9	1.3

five native and six alien forb species were encountered. The most common post-burn species following three successive spring fires were *Erodium botrys,* an alien introduced from Europe, and the native *Trifolium microcephalum.* Neither of these increased substantially following fall burns (Table 5). Alien and native forbs together accounted for 7.2 of the 11.2 species per plot (64%) (as opposed to 1.8 of 4.8 or 38% before burning and 2.8 of 5.8 or 48% of the control plots) and 7.8 of the 15.9 g/0.05 m^2 (49%) (compared with 0.2 of 15.2 g/0.05 m^2 or 1.3% preburn and 1.3 of 11.7 or 11% of the control plots) biomass.

CONCLUSIONS

The annual grasslands that characterize much of the foothills of the southern Sierra Nevada are dominated by species introduced from Europe and other Mediterranean climate areas. The near complete dominance of these species has been largely attributed to their resistance to disturbance associated with grazing, erosion and agriculture. The role of fire in the competitive interaction between native and alien species in California's grasslands is uncertain. In natural areas such as national parks and nature preserves there is interest in reestablishing the native herbaceous flora. The experiments reported here indicate that both the frequency and seasonality of fire can influence grassland species composition and biomass. Both spring and fall burning increased the total number of species. Repeated burns both decreased the relative dominance of introduced grasses and increased the diversity and dominance of native and alien forbs. Neither single nor repeated (up to three times) fall or spring burns resulted in the establishment of additional species of native grasses in the study area. This may, in part, be attributed to the fact that native grass species and thus seed sources are rare in this community.

Although both fall and spring burns favored forb establishment at the expense of grasses, they had minimal effect on total biomass when maintained over three years. Fall burns tended to increase the number and biomass of alien forbs more than that of native species whereas spring burns favored both about equally. Thus, although the number and biomass of alien grasses may be reduced by regular and repeated burning (especially late in the season), both alien and native forbs will be increased.

In the case of both fall and spring burning, alien grasses quickly regained their pretreatment dominance when burning was halted following one or two treatments. From a management perspective, this means that whatever gains might be realized from a program of regular burning could be quickly lost if that program were suspended. Frequent burning will almost certainly be needed to maintain long-term changes if such is even possible.

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CALIFORNIA BOTANICAL SOCIETY

Meeting Program 1989–1990

"PLANT CONSERVATION RESEARCH NEEDS FOR THE 1990'S"

8:00 p.m. University of California, Berkeley 159 Mulford Hall

DATE	SPEAKER AND TOPIC
19 OCT	Mr. Niall McCarten, Dept. of Integrative Biology, Univ. California, Berkeley "Plant extinction rates in the California flora: outlook for the future"
16 NOV	Mr. Timothy Krantz, Botanical Consultant, Haward, CA "Rare and endemic plants of the Big Bear Preserve, San Bernardino County"
18 JAN	Mr. James Bartel, U.S. Fish and Wildlife Service, Sacramento, CA "Rarity or endangerment: a call for a consensus on priorities"
17 FEB*	Dr. Michael Soule, Dept. of Environmental Studies, Univ. California, Santa Cruz "A zoologist's perspective on plant conservation biology"
15 MAR	Dr. Thomas Griggs, The Nature Conservancy "Restoration of Riparian Systems"
19 APR	Dr. Bruce Pavlik, Dept. of Biology, Mills College, Oakland, CA "Genetic and ecological aspects of rare plant reintroduction: the case of *Amsinckia grandiflora*"
17 MAY**	Ms. Roxanne Bittman, Natural Diversity Data Base, Calif. Dept. of Fish and Game, Sacramento "Plant conservation research needs for the 1990's"

* **Annual Banquet**—location to be announced.

** Meeting to be held at University of California Botanical Garden, Strawberry Canyon, Berkeley.